

# **Transport of Sediments and Strata Formation on the Adriatic Epicontinental Shelf**

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## **LONG-TERM GOALS**

The long-term goal of our research program is to advance scientific understanding and predictive modeling of sediment-transport processes in coastal and estuarine environments. The processes are important to the Navy because they define the tactical environment in shallow water and directly affect optical and acoustic properties of the water column. The resulting seabed structure and morphology affect acoustic backscatter and ability to locate objects on or near the bottom. Predictive capabilities for coastal sedimentary processes are also of great interest to geologists, coastal resource managers, and environmental scientists interested in mitigating coastal hazards, protecting or restoring coastal resources, or remediating contaminated marine environments.

## **OBJECTIVES**

EuroSTRATAFORM is a coordinated research program to measure and model the oceanic and geologic processes that erode, transport, and deposit sediment on continental margins, focused particularly on those events that form and destroy beds over time scales ranging from weeks to years. EuroSTRATAFORM hopes to transfer knowledge accumulated in the ONR STRATAFORM program, incorporate the expertise and insight of European investigators, and test our developing understanding of depositional marine systems in a different environmental context.

## **APPROACH**

The objectives of our proposed studies are as follows:

- Participate in the Apennine field study, measuring key processes in the benthic boundary layer, the response of bottom sediments and bottom morphology to sediment input, and oceanographic forcing during winter months at two sites in Apennine study area.
- Develop a regional model of sediment transport and compare model results with measurements, with particular emphasis on the relationship between suspended-sediments and bottom sediments.

- Develop and test new methods of estimating bottom sediment size.

## WORK COMPLETED

### Participation in the Po and Apennine Sediment Transport and Accumulation (PASTA) Experiment

**Tripod Deployments** – The USGS deployed three tripods in the northwestern Adriatic Sea as part of the PASTA experiment. Two tripods (the flow tripod and the particle tripod) were deployed near the sand-mud transition (9-m depth) about 0.6 nautical miles off the mouth of the Chienti River near the town of Civitina. These tripods were separated about 30 m apart (along isobath) and supported instruments from the USGS and Dalhousie University to measure flow, temperature, salinity, pressure, surface and near-bottom wave motions, suspended-particle size, suspended-particle concentration, bed-sediment size, and bed topography. The third tripod (Geoprobe tripod) was deployed directly offshore at a depth of ~20 m, and supported USGS instruments to measure flow, temperature, salinity, pressure, near-bottom wave motions, and suspended particle concentration. The three tripods were deployed in early November from the B/O Garcia del Cid, recovered, serviced, and redeployed in mid February from the R/V Seward Johnson II, and finally recovered in late May, again from the R/V Seward Johnson II.

Data recovery rate was excellent. Complete records for the two deployments were obtained from both acoustic Doppler current meters, all three acoustic Doppler velocimeters, both pulse-coherent acoustic Doppler profilers, both acoustic backscatter sensor profilers, both temperature-salinity loggers, and most of the sensors logged by these sensors. The imaging/profiling sonar system provided images of the seafloor at the 9-m site for about six weeks in the first deployment, and for the entire second deployment. Usable optical backscatterance and transmissivity data, including LISST measurements during the first deployment, were obtained for the first month or so before fouling.

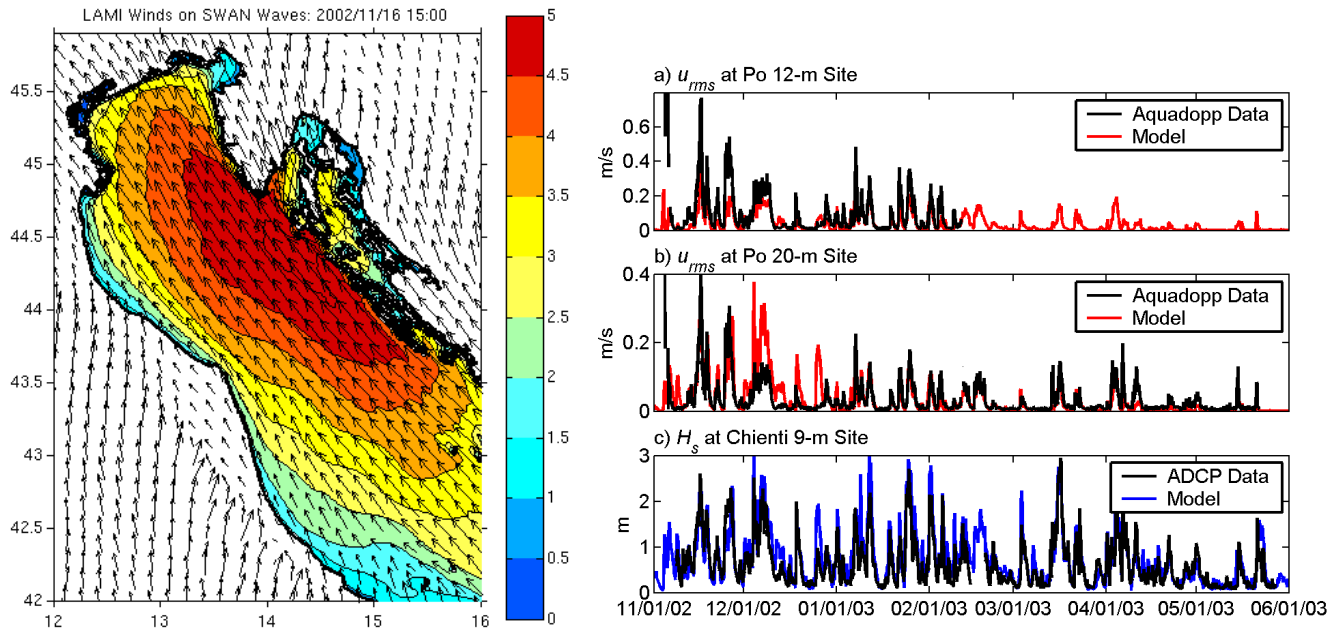
**Mapping** – The USGS surveyed five separate sites on the Apennine margins with side-scan sonar to characterize bottom conditions near tripod locations. We used a Klein model 595 system with a dual-frequency towfish (model 422S-101AF). Data were collected primarily at 100 KHz, usually over a 200-m swath width. Tracklines were spaced ~150 m apart. The data were recorded digitally along with GPS navigation data from the ship and post-processed to create digital mosaics.

Detailed surveys were performed at the Pescara 10 and 20-m sites in March 2003, and conditions at the Pescara 50-m site were mapped in June 2003 during an unsuccessful search for the IMS - Spain (Puig/Cacchione) mooring. A detailed survey of the 10-m Po de Tolle site also made in June, during an unsuccessful search for the Univ. of Washington (Ogston) tripod.

### Sediment-Transport Modeling

**Wave Modeling** – In collaboration with R. Signell (NATO SACLANT Centre, La Spezia), S. Carniel (National Research Council, Venice), and J. Chiggiato, (Servizio Meteorologico Regionale, Bologna), we have implemented realistic simulations of wave, circulation, and sediment transport for the Adriatic Sea north of the Gargano Peninsula. Wave modeling was performed on a 2-km grid using the SWAN model forced with winds from the Local Area Model Italy (LAMI) 7-km non-hydrostatic meteorological model. Wave estimates using SWAN with LAMI winds agree closely with buoy data. SWAN simulations have been completed for the PASTA experiment period (November 1, 2002

through June 1, 2003) and results (significant wave height, period, direction, and near-bottom orbital velocities) are available at three-hour intervals on the 2-km grid.



**Figure 1.** A snapshot of modeled wave heights in the Adriatic Sea is shown in the left panel. Blue shading in shallow waters of the Italian coast indicate low wave heights (~1.5-m) and dark orange shading in the north indicates high waves (~5 m). The overlain wind vectors point mostly northwest. The three panels on the right show time series of measured and modeled waves at three locations for the 8-month experiment. The top two subpanels show good agreement between measured (black lines) and modeled (red lines) wave-orbital velocities at 12 and 20-m depth off the Po River Delta. The bottom subpanel shows good agreement between wave heights measured (black line) and modeled (blue line) at 9-m depth off the Chienti River. (LAMI wind data courtesy Ufficio Generale per la Meteorologia and R. Signell, SACLANT Centre; wave-orbital velocities courtesy of P. Traykovski, WHOI.)

**Circulation and Sediment-Transport Modeling** - We have begun modeling the northern Adriatic Sea with TOMS, the terrain-following ocean modeling system developed with NOPP funding. Coarse-grid (4-km) simulations of circulation have been completed using forcing from LAMI products, measured Po River discharge, and climatological discharges from other rivers. Initial simulations of sediment resuspension and transport during the PASTA experiment have run successfully, using SWAN output for wave forcing and uniform initial distributions of fine bottom sediments.

**Prototype Sediment Camera**— A prototype underwater camera system was developed for this project to take repetitive microscopic images of the seabed from a tripod on the sea floor. The images, which record changes in seabed sediment over time, can be used to study how changes in sediment grain size influence rates of sediment movement.



**Figure 2. Image of the seafloor obtained at the 9-m Chienti River site with the prototype sediment camera, showing shell fragments, fecal deposits, and silt grains. Field of view is approximately 7 mm wide.**

The camera system consists of five major components: power pack, water pump, digital camera, electronic controller, and miniwinch, all designed to be mounted on a tripod that sits on the sea floor. So as not to interfere with the current flow or with other data-gathering instruments on the tripod, the camera is winched up and down 1 m from a protective housing every 12 hours. The electronic controller, a modified 12V lawn-irrigation timer, determines the up-and-down movements and the bottom-pause time for the winch motor. The winch motor is connected to a spool with a line attached to the camera housing to raise and lower it to the seabed. The camera housing, about 10 lb negatively buoyant, contacts the seabed and remains there for about 4 minutes. During this time, the camera's internal timer triggers the camera and a synchronized ring-light flash and the camera takes one photograph. The electronic controller then raises the camera back into its protective polyvinyl chloride (PVC) housing. A mercury switch located at the top of the PVC housing triggers the electronic controller to stop the winch once the camera housing has reached its topmost position. The electronic controller also determines the start and stop times of a water pump, which circulates pressurized seawater through a series of tubes to the front window of the camera housing, keeping it sediment free. The water pump operates four times each day for 1 minute, just before and after the camera's twice-daily contact with the seabed.

A Canon D60 digital camera with a 6.3-megapixel CMOS (complementary metal-oxide semiconductor) sensor is the heart of the imaging system. The lens, which is capable of 1X to 5X magnification and is surrounded by a ring-light flash, produces well-focused images, resolving grain sizes in the silt range, shell fragments, and feces trails and pellets.

## **RESULTS**

Work in FY2003 resulted in a comprehensive set of data describing oceanographic conditions and sedimentary processes at the Chienti transect, and preliminary models results that will allow us to integrate these data with other measurements to better understand sediment dynamics in the Adriatic Sea and other shallow coastal regions.

Preliminary analyses of the tripod data indicate that sediment resuspension is frequent at both 9 and 20-m depths. At the Chienti 9-m site, resuspension occurs at unusually low shear stresses ( $\sim 0.04$  Pascals). Tidal and wind-driven currents play an important role in redistributing sediments through the

water column, and sediment concentrations and vertical distribution of sediment are both modulated with tides. Tidally averaged currents at the Chienti transect are dominated by the Western Adriatic Current (WAC), a buoyancy-driven flow that can be enhanced by Bora winds. Reversal of this current occurred during strong Scirocco wind events, but between late November and mid-March, southward flow dominated. Modeled wave heights displayed substantial spatial variability, suggesting that variations in fetch and direction of wave approach may cause important variations in sediment resuspension along the coast.

Limited data from the new camera system indicates that the imaging system provides important new data, and that the mounting system must be redesigned.

## **IMPACT/APPLICATIONS**

These data will be integrated with measurements of other PASTA researchers and those of other participants in Adriatic experiments last winter. Combined, this will be one of the most detailed and comprehensive studies of circulation and sediment dynamics in a coastal sea. Analyses of these data, and their use in testing and improving models, will likely yield new insights to coastal processes.

## **RELATED PROJECTS**

**USGS Community Sediment-Transport Modeling Project** – USGS participation in EuroSTRATAFORM is closely linked with the community sediment-transport modeling project because the outstanding data set from Adriatic experiments in 2002-2003 provides an unparalleled opportunity to test and improve models of circulation and sediment transport. As noted in the Long-Term Goals section, the USGS and ONR have significant overlapping scientific interest in coastal ocean processes. The USGS has contributed salary and operating expenses to the PASTA experiment, and will continue as a partner with ONR to help advance coastal ocean modeling capabilities.

**Instrumentation to Measure Bottom Roughness from GEOPROBE Tripods (Award Number: N0001401F0263)** – The USGS received ONR funding to develop the imaging/profiling sonar system. That project was completed in FY2002 with successful dockside testing of the new instrument. The new instrument was successfully deployed during the PASTA experiment, and obtained high-quality data. Plans and software for the system have been provided to other ONR investigators.

## **PATENTS**

A patent application for the sediment camera has been made.